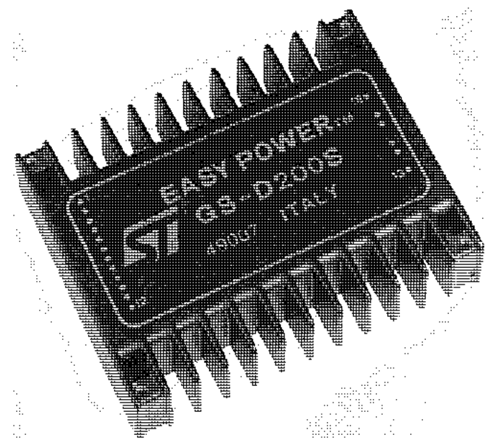
SGS-THOMSON MICROELECTRONICS

GS-D200
GS-D200S

2/2.5A BIPOLAR STEPPER MOTOR DRIVE MODULES

FEATURES

- Wide supply voltage range
- Full/Half step drive capability
- Logic signals TTL/CMOS compatible
- Programmable motor phase current and chopper frequency
- Selectable Slow/Fast current decay
- Synchronization for multimotor applications
- Remote shut-down
- Home position indication



DESCRIPTION

The **GS-D200** and the **GS-D200S** are drive modules that directly interface a microprocessor to a two phase, bipolar, permanent magnet stepper motors. The phase current is chopper controlled, and the internal phase sequence generation reduces the burden of the controller and it simplifies software development.
The **GS-D200** uses bipolar power outputs while the **GS-D200S** has powermos outputs to significantly reduce both commutation and conduction losses.
A further benefit offered by the **GS-D200S** is the complete protection of the outputs against any type of shorts.

SELECTION CHART

Type Ordering Number	Phase Current (A)	Voltage Drop (V)	Supply Voltage (V)
GS-D200	1.0 nom. (0.5 to 2.0)	4.1 max.	10 to 46 5.0±5%
GS-D200S	2.0 nom. (0.5 to 2.5)	2.5 max.	12 to 40 5.0±5%

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter		Value	Unit
V_S	DC Supply Voltage (pin 18)	GS-D200 GS-D200S	48 42	V V
V_{SS}	DC Logic Supply Voltage (pin 12)		7	V
T_{stg}	Storage Temperature Range		– 40 to +105	°C
T_{cop}	Operating Case Temperature Range		– 20 to +85	°C

ELECTRICAL CHARACTERISTICS (T_A = 25°C and V_S=24V unless otherwise specified)

Symbol	Parameter	Test Conditions		Value		Unit
			Min	Typ	Max	
I_S	Quiescent Supply Current	Pin 18			20	mA
I_{SS}	Quiescent Logic Supply Current	Pin 12 V_{SS}=5V		60		mA
V_i	Input Voltage	Pin 3,4,6,7,10,11 Low High	 2		0.8 V_{SS}	V V
I_i	Input Current	Pin 3,4,6,7,10,11 V_i=Low V_i=High			0.6 10	mA µA
V_{sat}	Source/Sink Saturation Voltage(GS-D200)	Pin 14,15,16,17 I_O=1A			1.8	V
V_{sat}	Source/Sink Saturation Voltage(GS-D200S)	Pin 14,15,16,17 I_O=2A			1.8	V
I_{OL}	Current Limit Intervention	GS-D200S	5			A
f_C	Chopper Frequency			17		kHz
t_{clk}	Stepckl Width	Pin 6 (See fig. 1)	0.5			µs
t_s	Set Up Time	”	1			µs
t_h	Hold Time	”	1			µs
t_r	Reset Width	”	1			µs
t_{rclk}	Reset to Clock Set Up Time	”	1			µs

Figure 1: Signals Timing

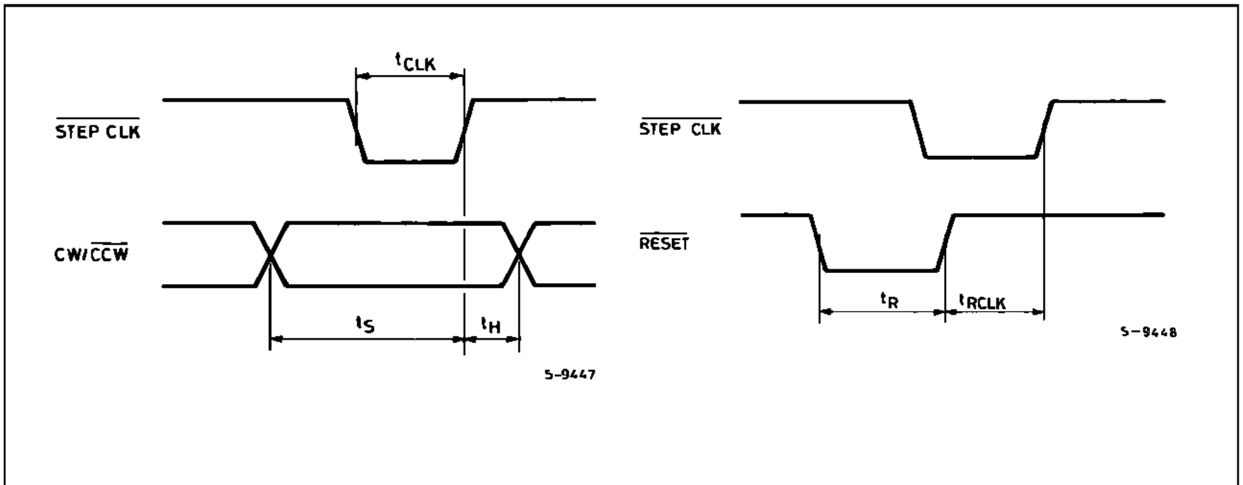


Figure 2: GS-D200 and GS-D200S Block Diagram

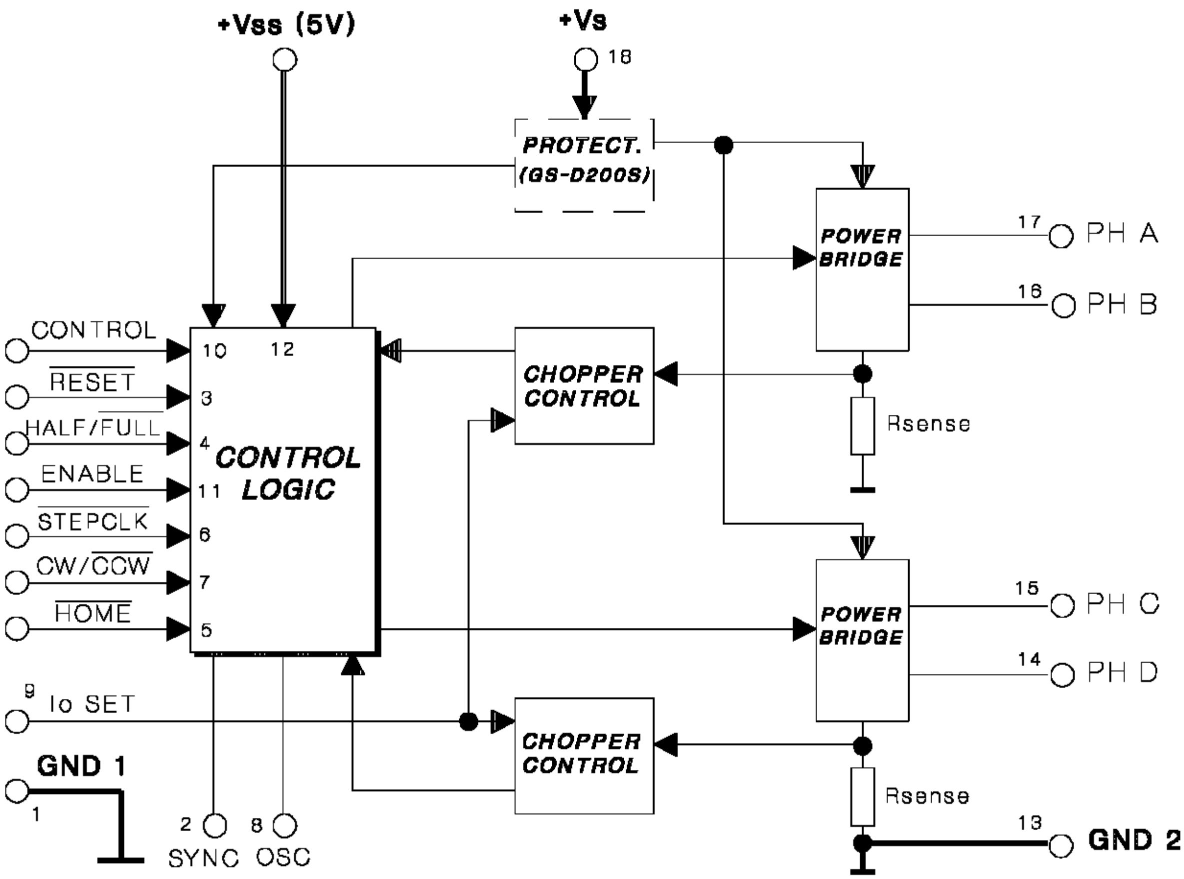


Figure 3: GS-D Modules Typical Application

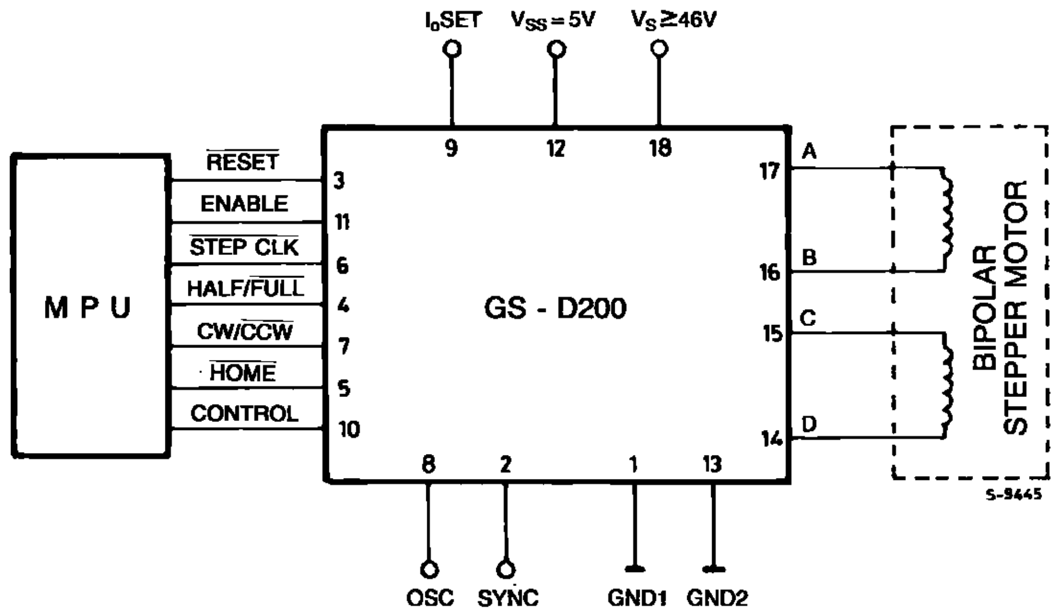
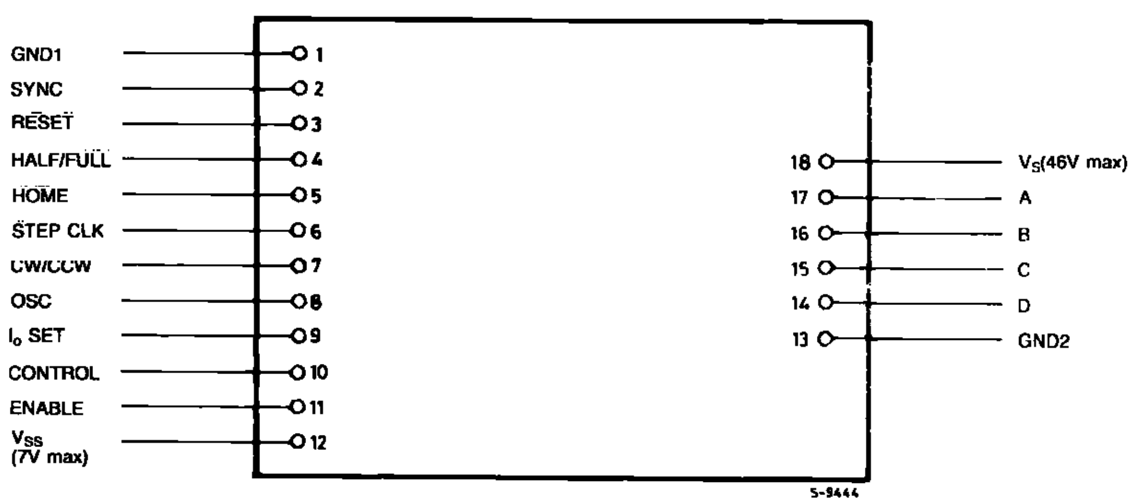


Figure 4: GS-D200 and GS-D200S Connection Diagram (Top view)



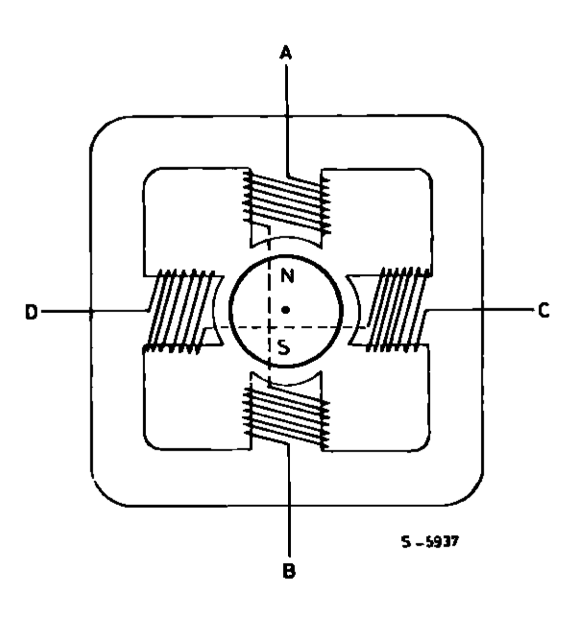
PIN DESCRIPTION

Pin	Function	Description
1	GND1	Return path for the logic signals and 5V supply.
2	Sync	Chopper oscillator output. Several modules can be synchronized by connecting together all Sync pins. This pin can be used as the input for an external clock source.
3	$\overline{\text{Reset}}$	Asynchronous reset input. An active low pulse on this input preset the internal logic to the initial state (ABCD=0101).
4	Half/$\overline{\text{Full}}$	Half/Full step selection input. When high or unconnected the half step operation is selected.
5	Home	When high, this output indicates that the internal counter is in its initial state (ABCD=0101). This signal may be used in conjunction with a mechanical switch to ground or with open collector output of an optical detector to be used as a system home detector.
6	$\overline{\text{Stepclk}}$	The motor is moved one step on the rising edge of this signal.
7	CW/$\overline{\text{CCW}}$	Direction control input. When high or unconnected clockwise rotation is selected. Physical direction of motor rotation depends also on windings connection.
8	Oscillator	The chopper oscillator timing, internally fixed at 17kHz, can be modified by connecting a resistor between this pin and V_{SS} or a capacitor between this pin and Gnd1. The oscillator input must be grounded when the unit is externally synchronized.
9	I_{oset}	Phase current setting input. A resistor connected between this pin and Gnd1 or V_{SS}, allows the factory setted phase current value (1A for GS-D200 and 2A for GS-D200S) to be changed.
10	Control	Logic input that allows the phase current decay mode selection. When high or unconnected the slow decay is selected.
11	Enable	Module enable input. When low this input floats the outputs enabling the manual positioning of the motor. Must be LOW during power-up and down sequence, HIGH during normal operation.
12	V_{SS}	5V supply input. Maximum voltage must not exceed 7V.
13	GND2	Return path for the power section.
14	D	D output.
15	C	C output.
16	B	B output.
17	A	A output.
18	V_S	Module and motor supply voltage. Maximum voltage must not exceed the specified values.

BIPOLAR STEPPER MOTOR BASICS

Simplified to the bare essentials, a bipolar permanent magnet motor consists of a rotating-permanent magnet surrounded by stator poles carrying the windings (fig. 5).

Figure 5: Simplified Bipolar Two Phase Motor



Bidirectional drive current is imposed on windings A-B and C-D and the motor is stepped by commutating the voltage applied to the windings in sequence. For a motor of this type there are three possible drive sequences.

One-Phase-on or Wave Drive

Only one winding is energized at any given time according to the sequence :

AB - CD - BA - DC

(BA means that the current is flowing from B to A).

Fig. 6 shows the sequence for a clockwise rotation and the corresponding rotor position.

Two-Phase-on or Normal Drive

This mode gives the highest torque since two windings are energized at any given time according to the sequence (for clockwise rotation).

AB & CD ; CD & BA ; BA & DC ; DC & AB

Fig. 7 shows the sequence and the corresponding position of the rotor.

Half Step Drive

This sequence halves the effective step angle of the motor but gives a less regular torque being one winding or two windings alternatively energized. Eight steps are required for a complete revolution of the rotor.
The sequence is:

AB ; AB & CD ; CD ; CD & BA ; BA ; BA & DC ; DC ; DC & AB

as shown in fig. 8.

By the configurations of fig. 6, 7, 8 the motor would have a step angle of 90 ° (or 45 ° in half step). Real motors have multiple poles pairs to reduce the step angle to a few degrees but the number of windings (two) and the drive sequence are unchanged.

Figure 6: One-Phase-on (Wave Mode) Drive

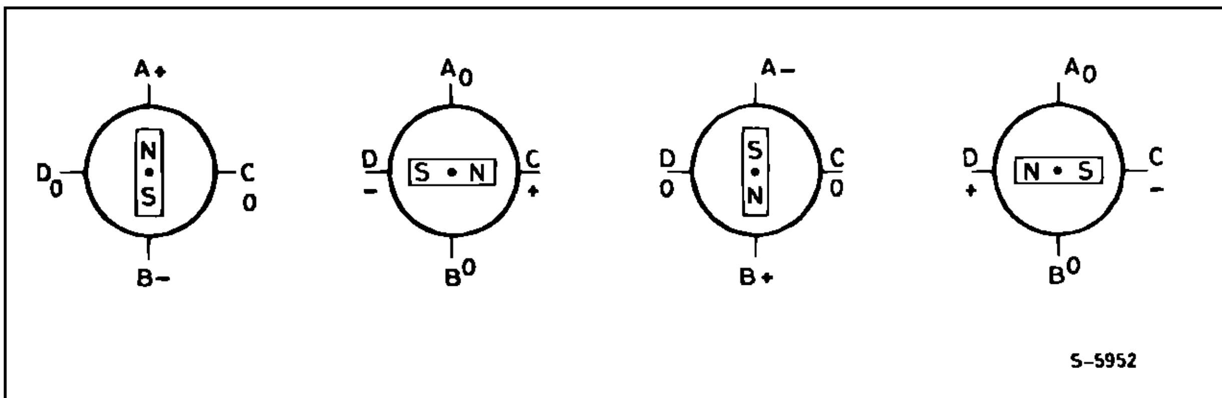


Figure 7: Two-Phase-on (Normal Mode) Drive

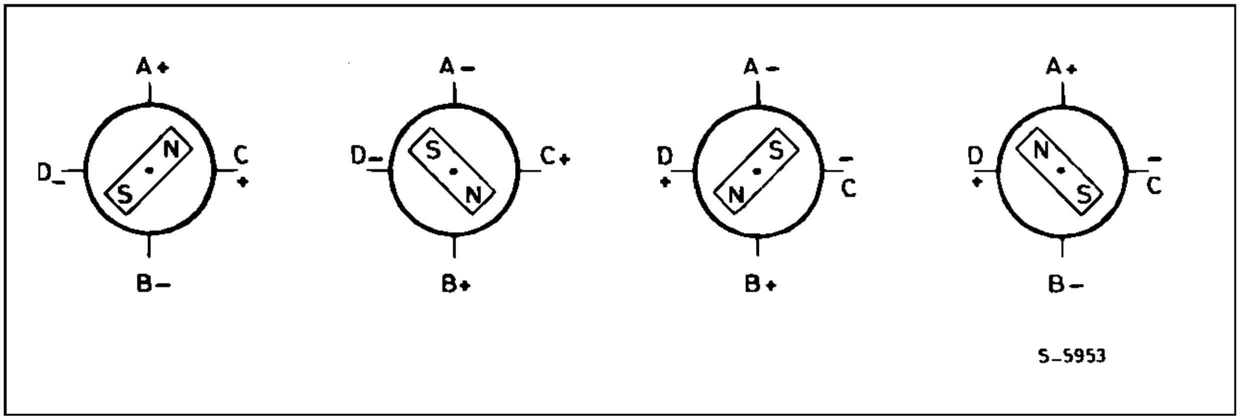
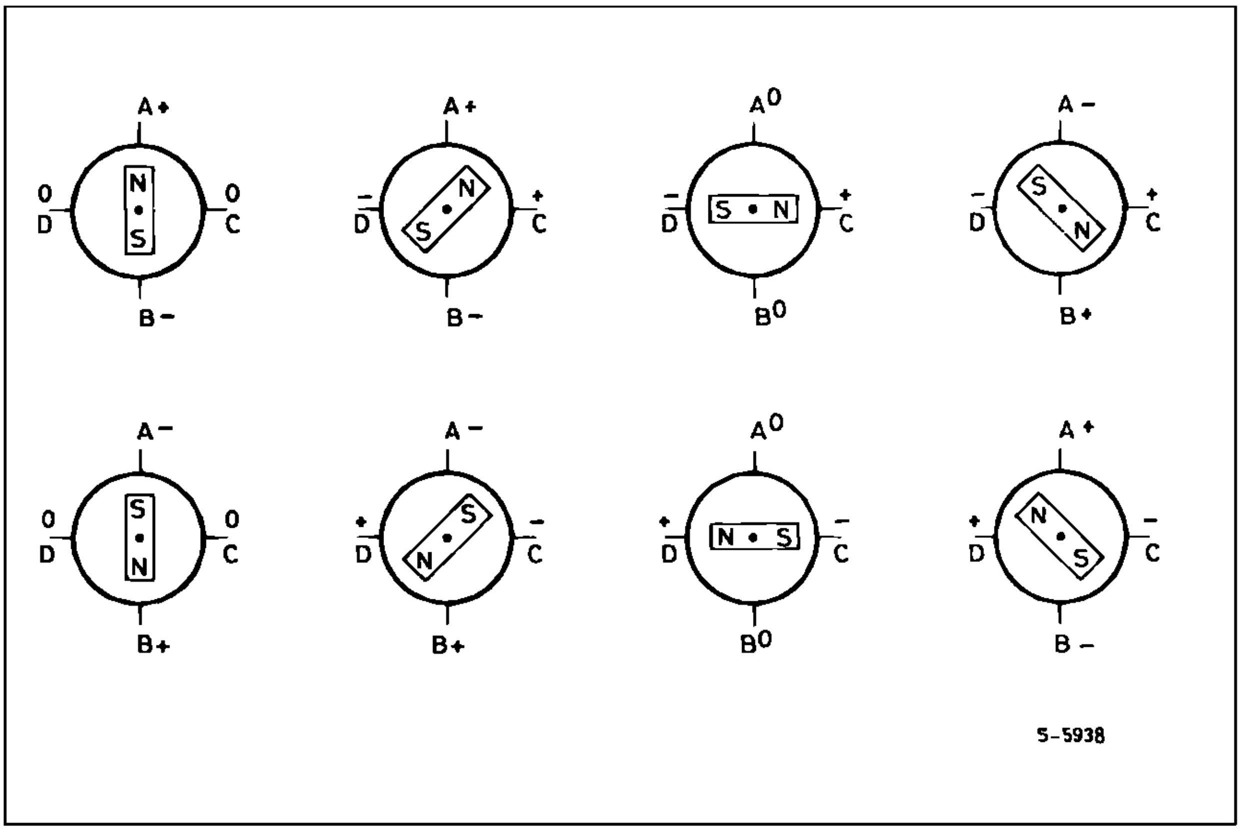


Figure 8: Half Step Sequence



PHASE SEQUENCE GENERATION INSIDE THE GS-D200/GS-D200S

The modules contains a three bit counter plus some combinational logic which generate suitable phase sequences for half step, wave and normal full step drive. This 3 bit counter generates a basic eight-step Gray code master sequence as shown in fig. 9. To select this sequence, that corresponds to half step mode, the HALF/$\overline{\text{FULL}}$ input (pin 4) must be kept high or unconnected.

The full step mode (normal and wave drive) are both obtained from the eight step master sequence by skipping alternate states. This is achieved by forcing the step clock to bypass the first stage of the 3 bit counter. The least significant bit of this counter is not affected and therefore the generated sequence depends on the state of the counter when full step mode is selected by forcing pin 4 (HALF/$\overline{\text{FULL}}$) low. If full step is selected when the counter is at any odd-numbered state, the two-phase-on (normal mode) is implemented (see fig. 10).

On the contrary, if the full mode is selected when the counter is at an even-numbered state, the one-phase-on (wave drive) is implemented (see fig. 11).

Figure 9: The Eight Step Master Sequence corresponding to Half Step Mode.

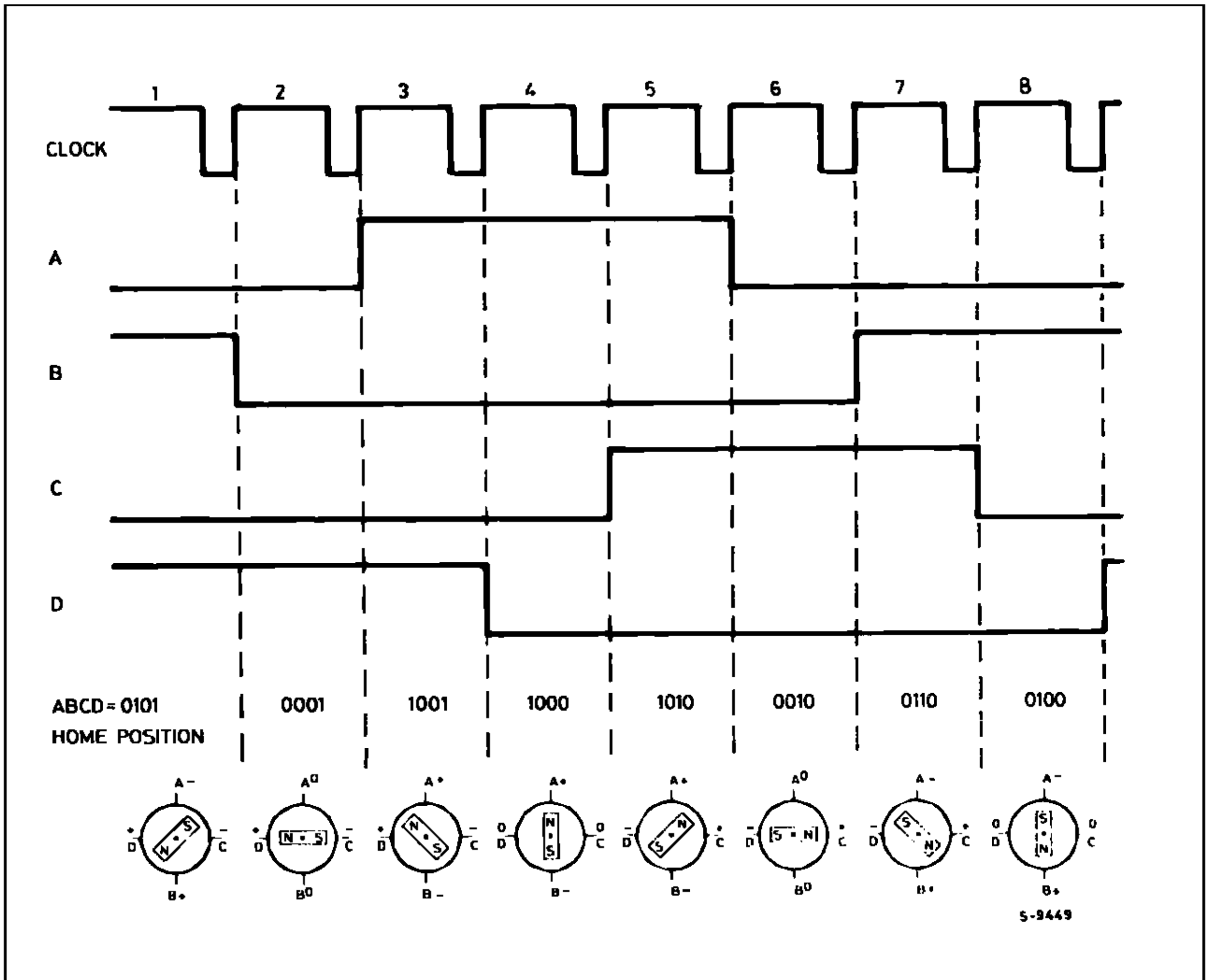


Figure 10: Two-Phase-on (Normal Mode) Drive

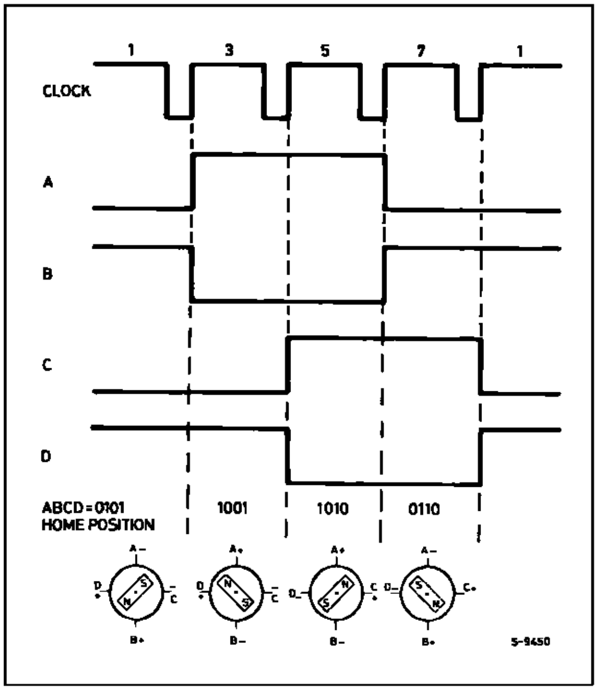
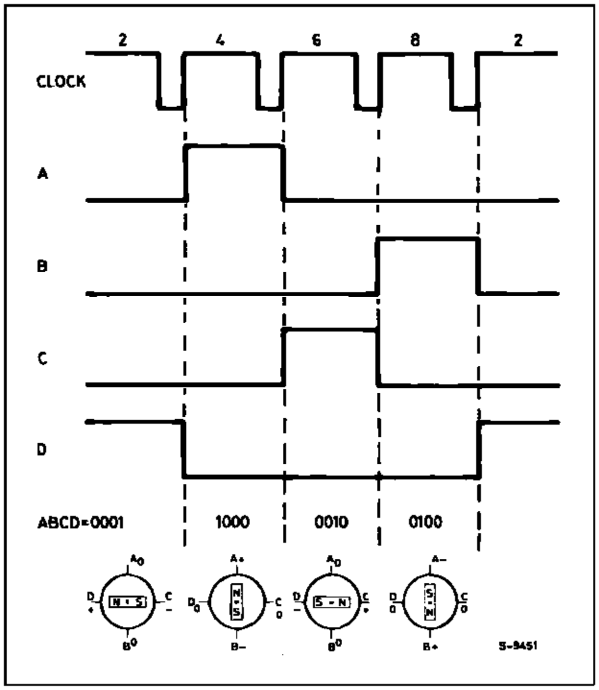


Figure 11: One-Phase-on (Wave Mode) Drive



RESET, ENABLE AND HOME SIGNALS

The $\overline{\text{RESET}}$ is an asynchronous reset input which restores the module to the home position (state 1 : ABCD = 0101). Reset is active when low.

The $\overline{\text{HOME}}$ output signals this condition and it is intended to be ANDed with the output of a mechanical home position sensor.

The ENABLE input is used to start up the module after the system initialization. ENABLE is active when high or unconnected.

MOTOR CURRENT REGULATION

The two bipolar winding currents are controlled by two internal choppers in a PWM mode to obtain good speed and torque characteristics.
An internal oscillator supplies pulses at the chopper frequency to both choppers.

When the outputs are enabled, the current through the windings raises until a peak value set by I_{oset} and R_{sense} (see the equivalent block diagram) is reached. At this moment the outputs are disabled and the current decays until the next oscillator pulse arrives.

The decay time of the current can be selected by the CONTROL input (pin 10). If the CONTROL input is kept high or open the decay is slow, as shown in fig. 12, where the equivalent power stage of GS-D200, the voltages on A and B are shown as well as the current waveform on winding AB.

When the CONTROL input is forced low, the decay is fast as shown in fig. 13.

The CONTROL input is provided on GS-D200 and GS-D200S to allow maximum flexibility in application.

If the modules must drive a large motor that does not store much energy in the windings, the chopper frequency must be decreased: this is easily obtained by connecting an external capacitor between OSC pin and GND1.

In these conditions a fast decay (CONTROL LOW) would impose a low average current and the torque could be inadequate. By selecting CONTROL HIGH, the average current is increased thanks to the slow decay.

When the GS-D200S is used in the fast-decay mode it is recommended to connect external fast recovery, low drop diodes between each phase output and the supply return (GND). The slow-decay should be the preferred operating recirculation mode because of the lower power dissipation and low noise operations.

Figure 12: Chopper Control with Slow Decay

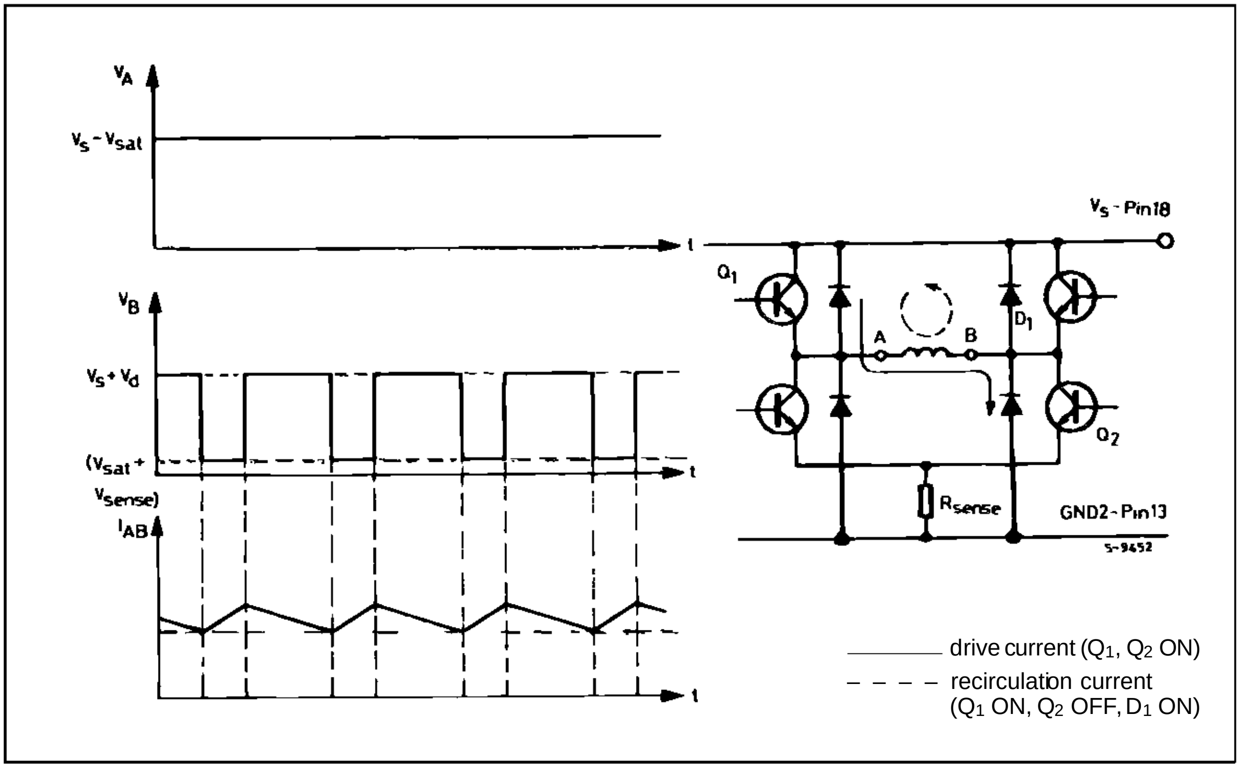
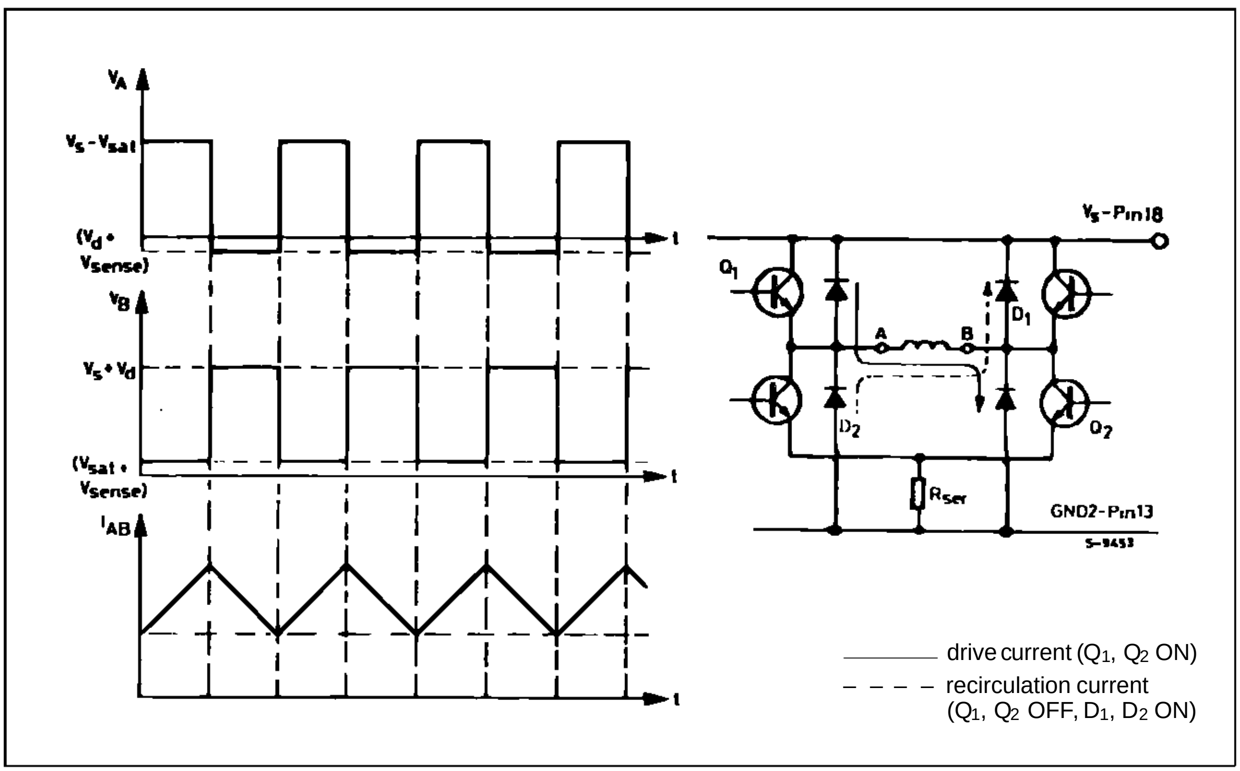


Figure 13: Chopper Control with Fast Decay



USER NOTES

Supply Voltage

The recommended operating maximum supply voltage must include the ripple voltage for the V_S rail, and a 5V±5% for the V_{SS} line is required.
The two supply voltages must to be correctly sequenced to avoid any possible erroneous positioning of the power stages. The correct power-up and power-down sequences are:

Power-up
1) V_{SS} (5V) is applied with Enable = Low
2) Vs (the motor supply voltage) is applied
3) Enable is brougth High

Power-down
1) Enable is brougth Low
2) V_S is switched off
3) V_{SS} is switched off.

Case Grounding

The module case is internally connected to pin 1 and 13. To obtain additional effective EMI shield, the PCB area below the module can be used as an effective sixth side shield.

Thermal Characteristics

The case-to-ambient thermal resistance of the GS-D modules is 5°C/W. This produces a 50°C temperature increase of the module surface for 10W of internal dissipation.
According to ambient temperature and/or to power dissipation, an additional heatsink or forced ventilation may be required. (See derating curves).

Supply Line Impedance

The module has an internal capacitor connected accross the supply pins (18 and 13) to assure the circuit stability. This capacitor cannot handle high values of current ripple, and would be permanently damaged if the primary energy source impedance is not adequate.
The use of a low ESR, high ripple current 470µF capacitor located as close to the module as possible is recommended. Suitable units are the SPRAGUE type 672D, the SPRAGUE 678D, the RIFA type PEG 126 or any equivalent unit. When space is a limitation, a 22µF ceramic multilayer capacitor connected across the module input pins must be used.

Module Protections

The GS-D200 outputs are protected against occasional and permanent short-circuits of the output pin to the supply voltage. The GS-D200S outputs are also protected against short circuits to ground and to another output. When the current exceeds the maximum value, the output is automatically disabled.

The GS-D200S protection is of the latching type, i.e. when an overload condition is detected the unit outputs are disabled. To restart the operations it is necessary to disable the unit (pin 11=Low) or to switch off the supply voltage for at least 100ms.

Motor Connection

The motor is normally quite far from the module and long cables are needed for connection. The use of a twisted pair cable with appropriate cross section for each motor phase is recommended to minimize DC losses and RFI problems.

Unused Inputs

All the GS-D200 and GS-D200S logic inputs have an internal pull-up, and they are high when unconnected.

Phase Current Programming

The output current of the GS-D200 is factory set to 1A while the GS-D200S has a standard 2A value. The phase current value can be changed by connecting an appropriate resistor between pin 9 and ground or V_{SS} (see fig. 14). In the first case the phase current will decrease, in the latter it will increase.
The maximum phase current must be limited to 2A for the GS-D200 and 2.5A for the GS-D200S to avoid permanent damage to the module.

GS-D200 phase current programming:

I>1A $$Ri = \frac{10 - I}{0.993 \cdot I - 1} = k\Omega \qquad Ri \geq 8.2\ k\Omega$$

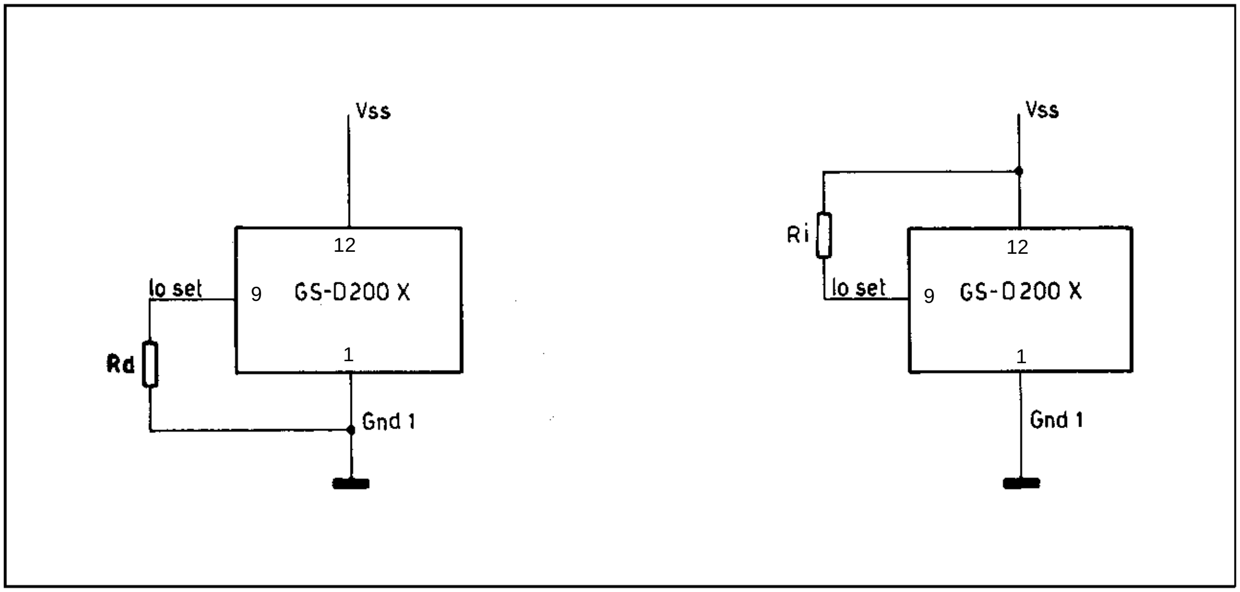
I<1A $$Rd = \frac{I}{1 - 0.993 \cdot I} = k\Omega$$

GS-D200S phase current programming:

I>2A $$Ri = \frac{10 - 0.33 \cdot I}{0.473 \cdot I - 1} = k\Omega \qquad Ri \geq 50\ k\Omega$$

I<2A $$Rd = \frac{I}{3.03 - 1.43 \cdot I} = k\Omega$$

Figure 14: GS-D200 and GS-D200S Phase Current Programming



Chopper Frequency Programming

The chopper frequency is internally set to 17kHz, and it can be changed by addition of external components as follows. To increase the chopper frequency a resistor must be connected between Oscillator (pin 8) and V_{SS} (pin 12, see fig. 15).
The resistor value is calculated according to the formula:

$$Rf = \frac{306}{fc - 17} = k\Omega \qquad \text{where } fc = kHz \quad Rf \geq 18k\Omega$$

To decrease the chopper frequency a capacitor must be connected between Oscillator (pin 8) and Gnd1 (pin 1). The capacitor value is calculated according to the formula:

$$Cf = \frac{80.5 - 4.7fc}{fc} = nF \quad \text{where } fc = kHz$$

Figure 15: Chopper Frequency Programming

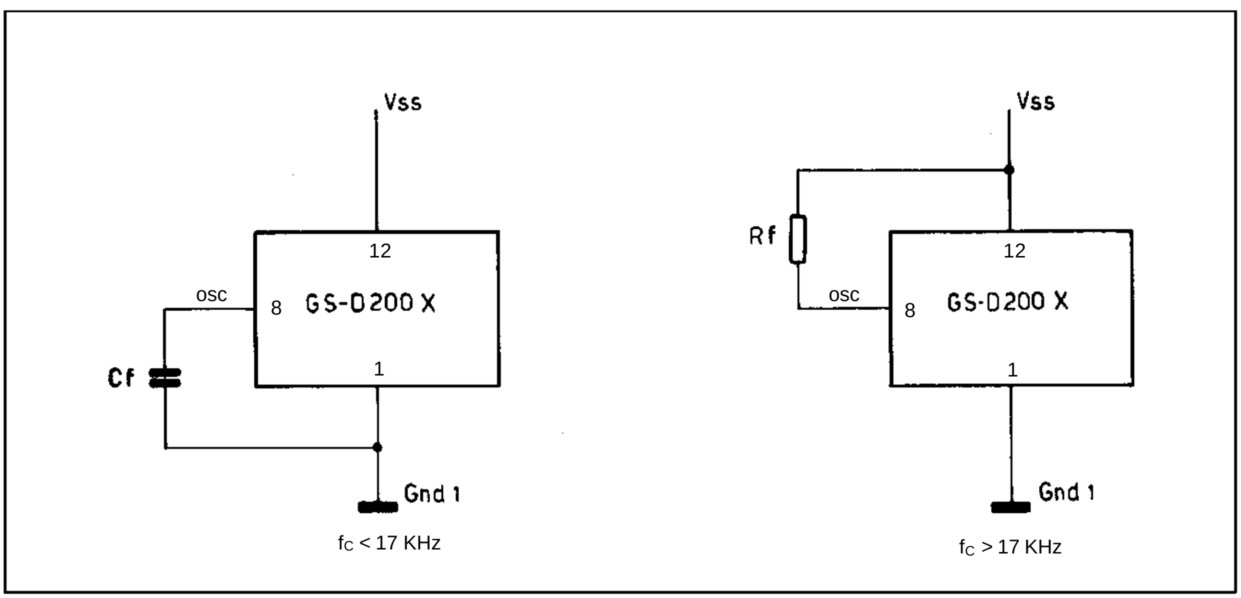


Figure 16: GS-D200 Free Air Derating Curve

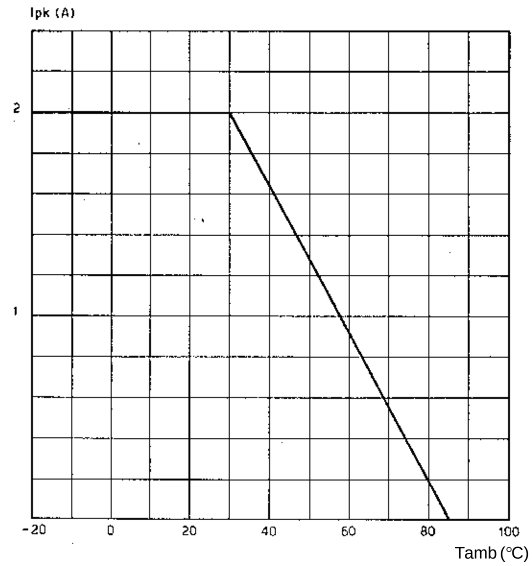
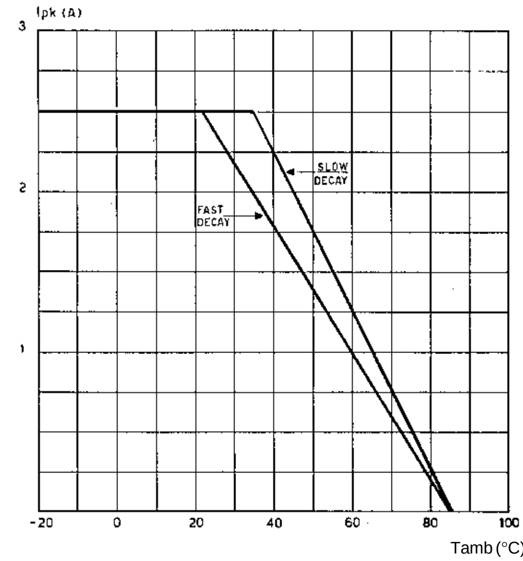


Figure 17: GS-D200S Free Air Derating Curve



MULTI MODULES APPLICATION

In complex systems, many motors must be controlled and driven. In such a case more than one GS-D200 or GS-D200 S must be used.
To avoid chopper frequencies noise and beats, all the modules should be synchronized.
If all the motors are relatively small, the fast decay may be used, the chopper frequency does not need any adjustement and fig. 18 shows how to synchronize several modules.

When at least one motor is relatively large a lower chopper frequency and a slow decay may be required: In such a case the overall system chopper frequency is determined by the largest motor in the system as shown in fig. 19.

Figure 18: Multimotor Synchronization. Small Motor and Fast Current Decay

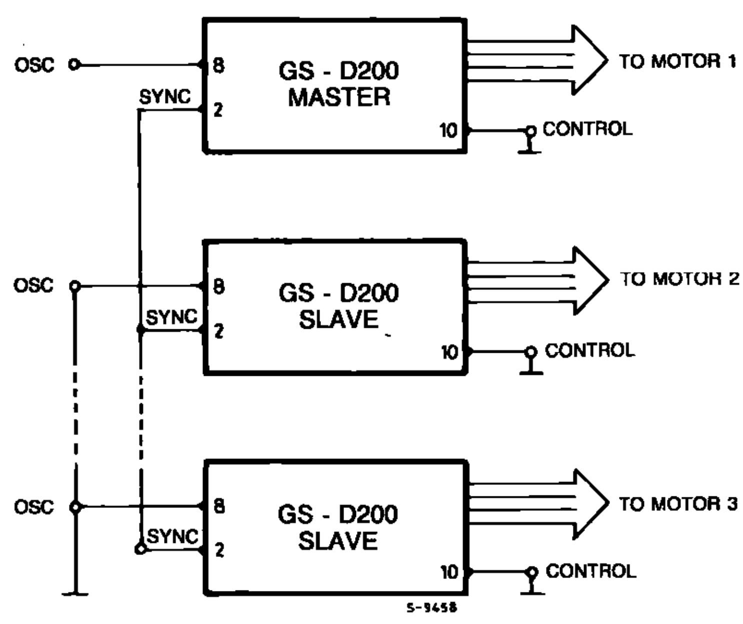
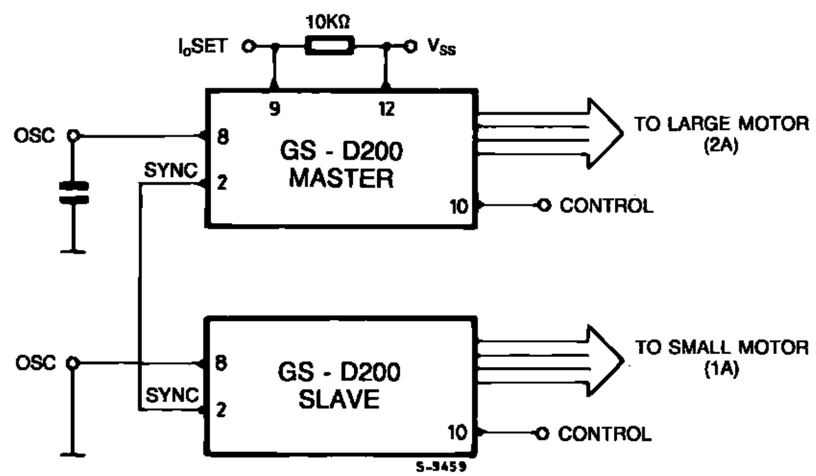


Figure 19: Multimotor Synchronization. Large and Small Motor. Slow Current Decay



THERMAL OPERATING CONDITIONS

In many cases the modules do not require any additional cooling because the dimensions and the shape of the metal box are studied to offer the minimum possible thermal resistance case-to-ambient for a given volume.

It should be remembered that these modules are a power device and, depending on ambient temperature, an additional heath-sink or forced ventilation or both may be required to keep the unit within safe temperature range. ($Tcase_{max}$ < 85 °C during operation).

The concept of maximum operating ambient temperature is totally meaningless when dealing with power components because the maximum operating ambient temperature depends on how a power device is used.

What can be unambiguously defined is the case temperature of the module.

To calculate the maximum case temperature of the module in a particular applicative environment the designer must know the following data:

– Input voltage

– Motor phase current

– Motor phase resistance

– Maximum ambient temperature

From these data it is easy to determine whether an additional heath-sink is required or not, and the relevant size i.e. the thermal resistance.

The step by step calculation is shown for the following example (GS-D200).

V_{in} = 40 V, I_{phase} = 1 A, R_{ph} Phase resistance = =10Ω, max. T_A = 50 °C

● Calculate the power dissipated from the indexer logic and the level shifter (see electrical characteristics):

$$P_{logic} = (5\ V \bullet 60\ mA) + (40\ V \bullet 20\ mA) = 1.1\ W$$

● Calculate the average voltage across the winding resistance:

$$V_{out} = (R_{ph} \bullet I_{out}) = 10\Omega\ \zeta\ 1\ A = 10\ V$$

● Calculate the required ON duty cycle (D.C.) of the output stage to obtain the average voltage (this D.C. is automatically adjusted by the GS-D200):

$$D.C. = \frac{V_{out}}{V_{in}} = \frac{10}{40} = 0.25$$

● Calculate the power dissipation of the GS-D200 output power stage. The power dissipation depends on two main factors:

– the selected operating mode (FAST or SLOW DECAY)

– the selected drive sequence (WAVE, NORMAL, HALF STEP)

FAST DECAY. For this mode of operation, the internal voltage drop is $Vsat_{source} + Vsat_{sink}$ during the ON period i.e. for 25 % of the time.
During the recirculation period (75 % of the time), the current recirculates on two internal diodes that have a voltage drop V_d = 1 V, and the internal sense resistor (0.5 Ω). For this example, by assuming maximum values for conservative calculations, the power dissipation during one cycle is:

$$P_{pw} = 1.1 \bullet [2\ V_{sat} \bullet I_{ph} \bullet D.C. + 2\ V_d \bullet I_{ph} \bullet (1 - D.C.) + 0.5 \bullet I_{ph}]$$

$P_{pw} = 1.1 \bullet [2\bullet1.8\bullet1\bullet0.25+2\bullet1\bullet1\bullet0.75 + 0.5 \bullet 1]$

$P_{pw} = 1.1 \bullet [0.9 + 1.5 + 0.5] = 3.19$ W

The factor 1.1 takes into account the power dissipation during the switching transient.

SLOW DECAY. The power dissipation during the ON period is the same. The RECIRCULATION is made internally through a power transistor ($V_{satsink}$) and a diode. The power dissipation is, therefore:

$P_{pw} = 1.1\bullet[2\ V_{sat}\bullet I_{ph}\bullet D.C.+(V_{sat}+V_d)\bullet I_{ph}\bullet(1-D.C.)]$

$P_{pw} = 1.1\bullet[2\bullet1.8\bullet1\bullet0.25 + (1.8 + 1)\bullet 1 \bullet 0.75]$

$P_{pw} = 1.1 \bullet [0.9 + 2.1] = 3.3$ W

WAVE MODE. When operating in this mode the power dissipation is given by values of FAST and SLOW DECAY mode, because one phase is energized at any given time.

NORMAL MODE. At any given time, two windings are always energized. The power dissipation of the power output stage is therefore multiplied by a factor 2.

HALF STEP. The power sequence, one-phase-on, two-phase-on forces the power dissipation to be 1.5 times higher than in WAVE MODE when the motor is running. In stall condition the worst case for power dissipation is with two-phase-on i.e. a power dissipation as in NORMAL MODE.

The following table summarizes the power dissipations of the output power stage of the GS-D200 when running for this example:

	Wave	**Normal**	**Half Step**
Fast Decay	3.19 W	6.38 W	6.38 W
Slow Decay	3.30 W	6.60 W	6.60 W

● Calculate the total power dissipation for the GS-D200 :

$P_{tot} = P_{logic} + P_{pw}$

In this example, for slow decay and normal mode

$P_{tot} = 1.1 + 6.6 = 7.7$ W

● The case temperature can now be calculated:

$T_{case} = T_{amb} + (P_{tot}\bullet R_{th}) = 55 + (7.7 \bullet 5) = 93.5\ °C$

● If the calculated case temperature exceeds the maximum allowed case temperature, as in this example, an external heat-sink is required and the thermal resistance can be calculated according to:

$$Rth_{tot} = \frac{T_{cmax} - T_{amb}}{P_{tot}} = \frac{85 - 55}{7.7} = 3.9\ °C$$

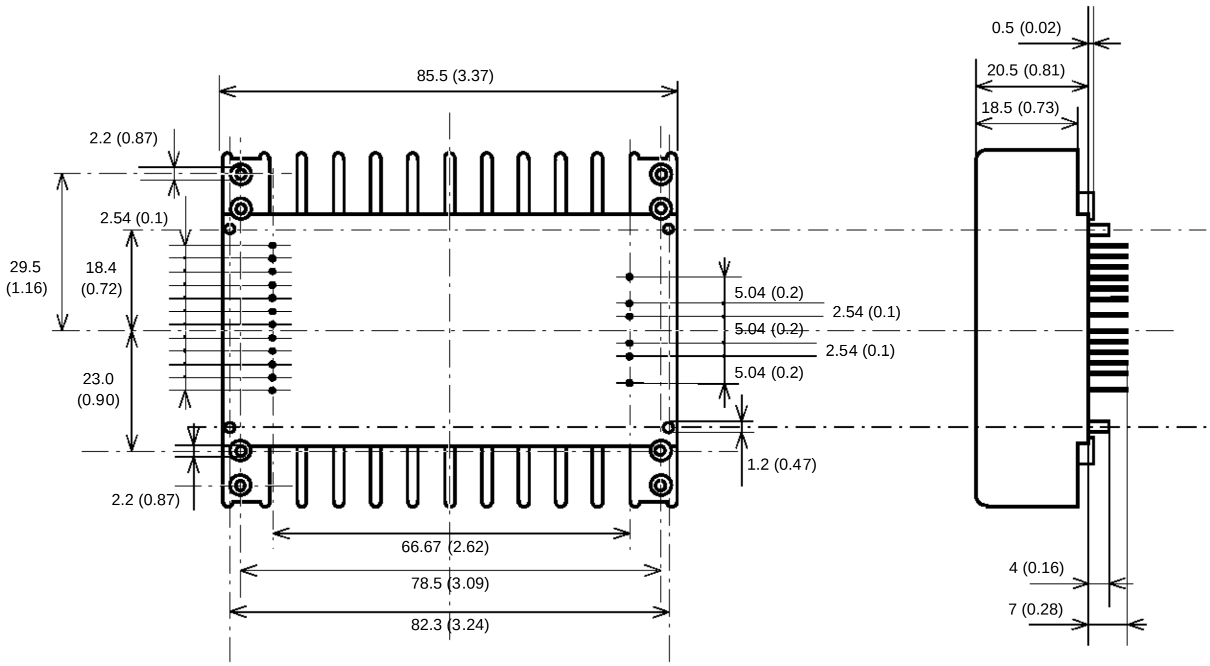
and then

$$Rth_{hs} = \frac{Rth \cdot Rth_{tot}}{Rth - Rth_{tot}} = \frac{5 \cdot 3.9}{5 - 3.9} = 17.7°C$$

The following table gives the thermal resistance of some commercially available heath-sinks that fit on the GS-D200 module.

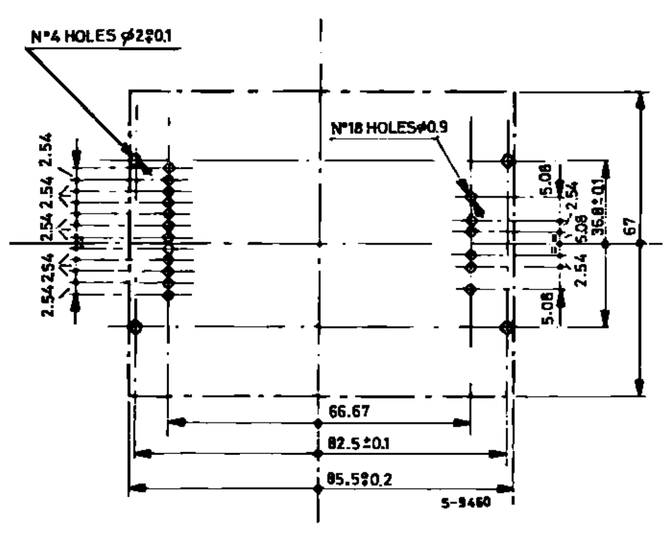
Manufacturer	**Part Number**	**R_{th} (°C/W)**	**Mounting**
Thermalloy	6177	3	Horizontal
Thermalloy	6152	4	Vertical
Thermalloy	6111	10	Vertical
Fischer	SK18	3	Vertical
Assman	V5440	4	Vertical
Assman	V5382	4	Horizontal

MECHANICAL DATA



Dimensions in mm

MOTHER BOARD LAYOUT



SGS-THOMSON MICROELECTRONICS